EFFECT OF RECHARGING AND PACKAGING ON MOISTURE LOSS AND QUALITY CHANGE IN SWEET POTATO DURING SHORT TERM STORAGE

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Declaration

This project report is my original work and has not been presented in any other University.

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Dedication

To my beloved husband Willy Shikuku Ooko, my lovely son Onyango Philemon and my adorable daughters Chelsea Atieno and Nancy Atieno.

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May Almighty God bless you all richly.

Abstract

This study was carried out to determine the effect of recharging and packaging on the shelf life of sweet potato roots during short-term storage. Freshly harvested potatoes from five genotypes were recharged by immersing in tap water for 0, 7 and 14 hours and thereafter evaluated for weight gain or loss, relative solute leakage , total soluble solids and dry matter content for 18 days.

Recharging led to significant weight gain, decreased weight loss and decrease in relative solute leakage in all the genotypes. However, recharging did not have significant effects on total soluble solids at the end of storage. Significant linear and/or quadratic effects on recharging duration treaments were observed in weight gain, weight loss, relative solute leakage and total soluble solids. The beneficial effect of recharging sweet potato was, therefore, due to replacement of lost moisture and decrease in moisture loss during storage following recharging. Recharging for 14h would be adequate to gain sufficient extension of shelf-life of sweet potato roots.

The effect of packaging on moisture loss and nutrient quality of two genotypes of sweet potato was also determined. Each of two genotypes, 'KEMB 10' and 'Yanshu" were recharged for 14 hours and packaged in kraft paper bag, perforated polythene bag and nylon gunny sack. The packaged potatoes were then stored at ambient conditions, with roots placed on an open plate as controls. During storage the potatoes were analysed for weight change, loss in reduced ascorbic acid, beta-carotene contents, total sugars and total soluble solids.

Packaging significantly decreased weight loss as well as reduced ascorbic acid and increased nutrient retention. Perforated polythene bag-packaged sweet potato roots

exhibited the highest decrease in these losses compared to the roots in other packages and in no package (control). Beta-carotene and total sugars increased during storage, with perforated polythene bag-packaged sweet potato roots having the highest values However, packaging had no significant effects on total soluble soild content of the roots.

Results of these studies show that recharging as well as packaging can be employed to improve the shelf-life of sweet potato. Recharging for 14h and packaging in perforated polythene bags can be recommended as the best combination of treatments to be applied in attempting to extend the shelf-life of sweet potato.

Table of contents

List of tables

List of Figures

List of appendices

List of abbreviations

% - percent

RH – relative humidity

K^+ - potassium ion

O_2 – oxygen

CO_2 – carbon dioxide

WVP – water vapour pressure

WVPD – water vapour pressure deficit

ml- millilitres

mg- milligrams

g- grams

µg - microgram

kg - kilograms

fwb – fresh weight basis

ha - hectares

PE – polythene

cm^2- square centimetre

cm^{-2} – per square centimetre

cm^{-3} – per cubic centimetre

h - hour

h^{-1} – per hour

^oC – degrees centigrade

b.p. – boiling point

$mbar^{-1}$ – per millibar

kPa – kilopascals

m – metres

km - kilometre

B_1 – thiamine

B_2 – riboflavin

B_3 – pantothenic acid

B_6 – pyridoxine

FAO – Food and Agriculture Organization

CIP – International Potato Centre

TCA- Trichloroacetic acid

KI – Potassium iodide

PEP – Petroleum ether

NaOH – Sodium hydroxide

CHAPTER ONE: INTRODUCTION

The sweet potato (*Ipomea batatas* L.) is an important food crop in the world, being cultivated in more than 100 countries. The roots are consumed fresh, or processed, can be used for production of animal feed together with leaves and vines, and have a potential as raw materials for manufacturing a variety of industrial products such as starches, glucose syrups and beverages (Woolfe, 1992).

The sweet potato is easy to grow, relatively pest resistant , adapted to tropical climates and is one of the highest producers of energy per hectare (Woolfe,1992). It therefore, merits attention as choice crop for production of adequate food for the world's poorest people in the tropics (Woolfe,1992).

Approximately 31000 hectares of sweet potato are planted in Kenya yearly, mainly on subsistence scale (Abubaker, 1990). The total annual production is estimated at 200 metric tonnes (MOA, 1987), with approximately one third of this being produced in Nyanza Province. The rest is produced in Western, Central, Eastern Coast and Rift Valley provinces. Several varieties are grown. Cultivation transcends all agro-ecological zones from marginal rainfall areas to high potential areas in the highlands. Most Kenyan farmers grow the sweet potato primarily for home consumption, although the surplus could be sold at the local markets to meet critical cash requirements for the family. In some parts of the country, for example Kirinyaga district, the crop is grown primarily for commercial purposes (Mutuura, 1990). The produce is sold in local markets, or to wholesalers who transport it to larger markets.

1.1 Statement of the Problem

Postharvest storage of sweet potatoes in Kenyan is not well developed. After harvest the roots deteriorate rapidly, mainly through water loss due to the prevailing high temperatures and low humidities. This deterioration frequently results in the sale of sweet potatoes of inferior quality (Woolfe, 1992). The deterioration proceeds during storage, marketing and in the market place (Woolfe, 1992). The poor harvesting methods that cause bruising also exacerbate the deterioration. There is very little formal sweet potato storage in Kenya. Roots are mainly left on the ground and harvested when and as they are needed. This has been referred to as 'piece-meal' harvesting and is perceived as a form of storage The 'piece-meal' harvesting however, has disadvantages. Many of the roots overmature before harvest and there is a possibilty of damage by pests like weevils, which is enhanced when harvesting is delayed (Onwueme, 1982) as well as destruction by marauding rodents, burrowing animals and nocturnal animals like the porcupine (Jenkins, 1982). Also as population increases and land gets scarce, retaining the sweet potato crop in the field for long will become a constraint in food production by occupying land that could be used for cultivation of other crops. Great need exists for developing adequate postharvest handling techniques to enable short-term or long-term storage of the sweet potatoes.

1.2 Research Justification

The main cause of sweet potato deterioration is transpiration (Quirien, 1998). The water loss causes shrivelling and changes in colour and texture, making them less appealing to the consumer (Woolfe, 1992). Any strategies, therefore, designed to reduce

water loss in storage would enhance the shelf-life of sweet potato roots. Methods which have been found to enhance shelf-life of other root vegetables such as carrots and cassava include curing, proper packaging (Burton, 1982) and recharging by dipping in water for limited periods (Shibairo, 1998).

1.3 Research Objectives

This study was, therefore, designed to determine the possible use of recharging and packaging to extend the shelf life of sweet potato roots during short-term storage. The specific objectives were as follows:

1. To determine the effect of recharging on moisture loss and quality changes of selected sweet potato genotypes during short-term storage.
2. To determine the effect of packaging material on moisture loss and nutrient content during short-term storage of selected sweet potato genotypes.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution of Sweet Potato in the World.

The sweet potato (*Ipomeu batatas* L.) is believed to have originated from the tropical Americas, from where it spread to most of the world's tropical, sub-tropical and warmer temperate regions. According to the FAO (1987), sweet potatoes are grown in 111 countries, of which 101 are classified as 'Developing Nations', since its domestication (Woolfe, 1992). It has, therefore, remained an important staple for many tropical communities.

2.2 Botany of Sweet Potato

The sweet potato is a creeping dicotyledonous plant belonging to the family Convolvulaceae. It is the only species of economic importance amongst the approximately 1000 species of the 50 genera in this family (Woolfe, 1992; Edmond and Ammerman, 1971).

The sweet potato plant can be divided into three basic parts, each of which has its own function (Woolfe, 1992). Above the ground, the sweet potato plant consists of the photosynthetic leaves , the petioles and vines. Below the ground, the plant consists of the root system that absorbs water and nutrients, and acts as an anchor for the plant. Here, the plant also stores excess energy in the roots. The root undergoes enlargement or development. The mature enlarged storage root ranges: in shape from almost spherical to spindle-shape, in length from a few centimetres to more than 30 cm and in weight from

0.1 kg to several kilogrammes. The skin colour varies depending on its anthocyanin and caroteinoid content (Woolfe, 1992).

The sweet potato genotypes are predominantly prostrate vining plants (although they can be ascending and sometimes also twining) and, contrary to most agricultural plants, they establish a relatively shallow and largely two-dimensional canopies. The long thin stems trail along the soil surface, sending roots into the soil at the nodes. The stem length varies with cultivar and is predominantly green, but some cultivars have vines with purple pigmentation (Woolfe, 1992). The leaves are arranged spirally on the stem and have petioles of varying lengths. Leaves are variable in size and shape, even within the same plant, and are usually green, but may also contain a considerable amount of purple pigmentation, especially along the veins (Woolfe, 1992).

2.3 Importance of the Sweet Potato

Among the world's root crops, the sweet potato ranks second only to the Irish potato in economic importance (Horton, 1988). The sweet potato plays many roles in diverse food systems across the world. The most typical system involves small-scale sweet potato production, primarily for household consumption and secondarily for livestock feed and for sale.

On a world scale, the sweet potato provides significant amounts of starch, protein and vitamins (FAO, 1987). The sweet potato is one of the most important starch producing crop in the world (Woolfe, 1992). Approximately 80 to 90% of the sweet potato dry matter (24 to 27% fresh weight) is made up of carbohydrates, which consist mainly of starch and sugars, with lesser amounts of pectins, hemicelluloses and cellulose

(Woolfe, 1992). The relative composition has considerable influence on quality factors such as texture, including firmness, dryness, mouthfeel and taste. The sweet potato crop as a world protein source is impressive (Walter *et al.*, 1984). It has been estimated that sweet potato yields on average 184 kg protein/ha, which compares favourably with the yields from wheat (200 kg/ha) and rice (168 kg/ha). The sweet potato has the potential of providing about 2 million tonnes of proteins world-wide. The sweet potato is one of the important sources of ascorbic acid (vitamin C) and contain moderate amounts of thiamin (B_1), riboflavin (B_2), niacin as well as pyridoxine (B_6), pantothenic acid (B_5) and folic acid. The potatoes have also been reported to contain satisfactory quantities of vitamin E. The yellow- red varieties are major sources of carotenoids, some of which act as precursors of vitamin A (Woolfe, 1992).

In Kenya, the sweet potato plays a major role in food security for subsistence farmers. It is grown as an 'insurance crop' to fall back on in case the main staple crops fail (Woolfe, 1992).

The sweet potato combines a number of advantages which give ample potential for alleviating future food shortages and malnutrition, arising from population growth and decreasing arable land. In many parts of the world, as population grows, fertile arable land available per head diminishes. This forces farmers to shift to the marginal land where heavier investments are required in order to realize adequate yeilds from the conventional crops. In these areas, the sweet potato does well.

In addition, the increasing flow of people away from the land to the urban areas puts a heavy burden on the diminishing number of rural food producers. Therefore, those food crops, such as the sweet potato which have highest yields per unit of time, even in

marginal conditions, have the potential to backstop the dwindling food supply (Woolfe, 1992)

2.4 Definition of Shelf-life

Shewfelt (1986) defined shelf-life as "the period that a product can be expected to maintain a predetermined level of quality under specified storage conditions". In asparagus, Hurst *et al.* (1993) defined shelf-life as "the number of days taken at 20°C before asparagus reaches the end of its marketable life". Shelf-life can be defined as "the time period a vegetable product can stay in storage and /or on the retail shelf while maintaining acceptability to the consumer, similar to produce harvested at an optimum stage for immediate consumption" (Dennis, 1981).

Postharvest mass loss in perishable crops is a widely used indicator of storage life (Ben-Yehoshua *et al.*, 1983 and Hurst *et al.*, 1993). Most weight loss is as a result of moisture loss. For fresh market sweet potato, moisture loss leads to loss of quality and shortens the shelf-life. The features that consumers use to measure freshness include firmness, succulence, sweetness, colour, lack of skin bruises and wounds (Woolfe, 1992). Maintenance of these qualities similar to be thoes at harvest is a major challenge in postharvest handling of sweet potatoes.

2.5 Factors Affecting Postharvest Moisture Loss

2.5.1 Size

Variation in size influences the rate of moisture loss from produce. Because evaporation is a surface phenomenon, the ratio of surface area to volume of the produce

is of critical importance. Harvested produce exhibit a wide range of surface area to volume ratios (Kays, 1991). Large root and tuber crops have ratios of between 0.2 to 0.5 $cm^2 cm^{-3}$ (Burton, 1982). Because of their small surface areas relative to volume, root and tuber crops generally lose moisture more slowly than leafy vegetables which have large surface area to volume ratios. In carrots, root fresh weight has been reported to determine moisture loss (Apeland and Baugerod, 1971; Shibairo, 1998) Apeland and Baugerod (1971), working with different size 'Nantes' carrots observed an increase in postharvest weight loss with a decrease in initial root weight; an approximate doubling of weight loss, expressed as a percentage of initial root weight, occurred as the initial weight decreased from 120g to 15g.

2.5.2 Surface characteristics

The outer layer of a sweet potato root, often referred to as 'skin' or periderm consists of three parts: phellem (cork), phellogen (cork cambium) and phelloderm (Edmond and Ammerman, 1971). Sweet potatoes have been reported to differ in periderm weight and the suberin and lignin deposition in its component cells (Woolfe, 1992). The environment may also determine these properties of the periderm. For example, exposure to excess moisture content as well as inadequate oxygen content suppresses suberization, resulting in retardated of tuber formation (Watanabe *et al* , 1968).

The peel of a potato tuber, which consists of suberized walls of dead cells in layers of 5 to 15 cells thick, is an effective barrier against water loss (Burton, 1982). The influence of the peel is indicated by a comparison between peeled and unpeeled potatoes.

Peeled potatoes lost 500 times more moisture than unpeeled potatoes (Burton, 1982). Therefore, moisture loss from potatoes is higher in damaged peels when the wounds have been sufficiently healed by curing.

During drying, evaporation decreases everyday as a consequence of the suberizing process in the potato. Burton (1982) reported that after 7 days, water loss was about 10 times less than after one day in potatoes during drying. This principle has been used in curing. Curing involves holding roots at 30 to 33°C and 85 to 95% relative humidity for 5 to 7 days. One of the major purposes of curing is to promote wound healing through the formation of a wound periderm. Because at the minimum, wounds occur at the stem and root ends of the storage roots, wound healing is essential for holding or storage. In addition, curing reduces desiccation and invasion by pathogens causing storage rots. Potato varieties may also play a role in evaporation. The specific moisture loss varied among 9 cultivars and ranged from 0.661 to 1.429×10^{-10} kg (kPa) (Slettenhaar, 1984).

2.5.3 Tissue permeability

Cell membrane permeability may differ among cultivars, age of the tissues and treatment of tissues (Kays, 1991). This may result in leakage of dissolved materials from cells and affect cells tugor (Berard and Lougheed, 1982). Because the plasma membrane offers resistance to water movement (Boyer, 1985), an increase in membrane permeability either at harvest or during storage will increase symplastic water flux, leading to an increase in transpiration. Electrolyte (Finlayson *et al.*,1989; Knowles *et al*

.1989) and solute (Pooviah and Leopold, 1976; Toivonen, 1992) leakage have been used as indicators of tissue permeability in vegetable root crops.

Several factors have been implicated in the change of membrane integrity during storage of vegetables. Finlayson *et al.* (1989) observed increased electrolyte leakage and disruption of membranes as temperatures increased in diseased carrots.

Carlin *et al.* (1990) observed an increase in potassium (K^+) leakage in carrots as carbon dioxide (CO_2) increased or oxygen (O_2) decreased. In potatoes, cultivars with higher levels of unsaturated fatty acids had lower rates of membrane leakage (Spychalla and Desborough, 1990). Thompson (1984) and Yoshida (1984) reported that the degree of fatty acids unsaturation in many tissues increased in response to low temperature. However, the relationship between tissue permeability and postharvest moisture loss during short-term storage in sweet potato has not been determined.

2.5.4 Cultivar differences

A very large number of sweet potato cultivars exists. Many of these cultivars have arisen through systematic breeding efforts, but an appreciable number of them have also arisen through natural hybridization and mutations. Sweet potato cultivars differ from one another in tuber skin colour, tuber texture, tuber flesh colour, tuber shape, leaf shape, rooting depth, maturity timing, disease resistance, and several other vegetative characteristics (Onwueme, 1982). The relationship between these parameters and the shelf-life of commercial cultivars has not been determined.

Burton (1982) suggested that the compactness and thickness of the cuticle or periderm could result in moisture loss differences among commodities, varieties and

species. How genetic differences in periderm characteristics influence moisture loss in sweet potato has not been determined. The shelf-life of sweet potato could be improved by breeding for desirable periderm characteristics to reduce transpiration losses. Differing stages of maturity can have a considerable effect, particularly if, as in the case of the potato tuber, the nature and structure of the outer layers change during development (Burton, 1973).

Cultivars differ in physiological characteristics such as cell turgor, respiration, soluble sugar content and the levels of amino acids, organic acids and phenolic substances (Phan *et al.*, 1973). The sugar content of a cell, a major contributor to osmotic potential increases during growth (Fritz and Weichmann, 1979; Weichmann and Kappe, 1977) and decreases during storage (Ben-Yehoshua, 1987; Nilsson, 1987). Exactly why sweet potato cultivars differ in moisture loss has not been determined.

2.5.5 Vapour pressure deficit and relative humidity

Transpiration in vegetables is a mass transfer process in which water vapour moves from the produce surface to the surrounding air. The driving force for transpiration, the vapour pressure deficit (VPD), is the difference between water vapour pressure (WVP) in the air and the equilibrium WVP of the vegetable (van den Berg, 1987). The relationship between VPD and the rate of transpiration is curvilinear (Burton, 1982). At a constant temperature, a 5% change in relative humidity (RH) has much larger effect on transpiration at high than at low RH: e.g. a decrease from 98 to 93% RH increases transpiration by 25%, whereas a decrease from 85 to 80% results in an increase of only 33% (Burton, 1982).

Recommended levels of RH for storing vegetables are a trade-off between desiccation of the products at low humidity and an increase in decay at high humidity (van den Berg and Lentz, 1996; van den Berg, 1981). The recommended optimum RH for sweet potato, however, is close to 85 to 95% RH, because decay at the low temperatures used is not a serious problem (Woolfe, 1992). Quality assessment by Shartuddin and Voican (1984) showed that storage at a lower RH (80 to 85%) substantially increased their moisture loss from 72 to 96% over a period of 4 months. Thus, storage at high RH is essential to prolong shelf life of sweet potatoes.

For long term storage, jacketed and 'Filacell' systems provide practical and not economical ways of maintaining water saturated atmosphere during storage (Raghavan *et al.*, 1990). The jacketed storage provides high humidity and maintains a uniform temperature and air movement (Lentz and Rooke, 1957). Other humidification systems including plastic packaging, sealed boxes and constant temperature cold rooms, obtained the same benefit as jacketed storage at high RH (Raghavan *et al.*, 1990).

Because at the retail level sweet potatoes are stored under variable temperatures and RHs for only a few days, the use of 'Filacell' and jacketed storage to reduce transpiration may not be economical. Alternative methods for short-term storage to reduce postharvest moisture loss are, therefore, needed. Before the development of such technologies, an understanding of the changes that occur in sweet potato tubers under retail shelve conditions is essential.

2.6 Control of Water Loss

When produce is severed from the parent plant, water uptake ceases, however, evaporation losses continue. Unless moisture loss is inhibited (e.g. by storing at high RH) or water is reintroduced, a water deficit occurs, resulting in reduced turgidity and an accelerated rate of quality loss and senescence.

2.6.1 Recharging

Recharging refers to dipping harvested plant products in water to replace the lost moisture. For many harvested products it is necessary to reintroduce water if the internal concentration has dropped below the desired level (Kays, 1991). Introduction of water is accomplished by using either moisture in the liquid or vapour phase. The physical state of water that can be used depends on the product, rate of uptake required, final concentration desired and intended use of the product. The introduction of vapour phase moisture requires considerably more time than water in the liquid phase. The use of water vapour, however, is essential for crop products that cannot withstand direct wetting (Wills *et al.*, 1981).

The rate of uptake of moisture is enhanced by a high WVPD between the atmosphere and the product, and a positive gradient favouring the movement from the atmosphere to the product. Increasing temperature and air movement also enhances the rate of uptake (Kays, 1991). Wills *et al* (1981), observed that for corn seed under various environmental conditions, the higher the RH, the greater was the difference in VPD thereby accelerating moisture uptake.

Uptake is greatly enhanced if the water temperature is less than that of the fruit (Kays, 1991). The colder water cools the fruit floating or submerged in it, decreasing the

volume of the gas atmosphere within the tissue. A partial vacuum is created that pulls water through the stem scar into the fruit until the internal and external pressures are balanced.

During retail marketing, water is often directly applied to a number of edible products (such as leaf lettuces (*Lactuca sativa*, L.), onions (*Allium cepa*, L.), celery (*Apium graveolens* var *dulce*, Pers.), kale (*Brassica oleracea* , L. Acephala group), kohlrabi (*Brassica oleracea*, L. Gongylodes group), parsley (*Petroselinum crispum*, (Mill.) Nym.), and watercress (*Nasturtium officinale*, R Br.)). In addition to decreasing product temperature and increasing RH, cold water sprays allow the uptake of some water by many products. Postharvest products vary widely in their ability to have water applied to their surfaces. Leafy crops that have high surface areas lose water quickly and generally benefit from water sprays. Unsprayed vegetables have been shown to display a 10-20% weight reduction during the first few days under stimulated retail conditions (Dipman *et al.*, 1939).

Shibairo (1998), observed that carrots benefited most from recharging (water uptake) as most of the weight lost was replaced. When roots are left in the hot sun after harvest, or during uncontrolled conditions of storage are exposed to high temperatures, moisture losses and the susceptibility to decay increase (Woolfe, 1992). Some cultivars develop pithiness, a texture defect resulting from an increase in volume of intercellular spaces in root tissue. Different stages of maturity can have a considerable effect, as in the case of the sweet potato on tuber development. There may also be postharvest changes in the permeability of the outer layers, for immature potato tubers, in which much of the

change (a 5- to 10-fold decrease) after storage for about 1 week at 10°C results from wound-healing.

The uptake of liquid phase water by products during cooling and handling operations can, in some instances, be undesirable in that it may introduce disease organisms into the product. For example, the use of water to float tomatoes (*Lycopersicon esculentum*, Mill.) out of large trucks can introduce water-borne disease organisms into the fruit through the stem scar. Some species such as cauliflower (*Brassica oleracea* L. Botrytis group), the floral parts of cut-flowers, raspberries (*Rubus idaeus* var. *strigosus*, (Michx.) Maxim) and mushrooms should never be in contact with water. The exposure of the surface of these products to free water causes rots. Proper sanitation is also important (e g., use of chlorine).

Because one of the causes of loss of sweet potato quality during storage is mainly due to moisture loss, reduction of moisture loss or replacement of the lost moisture may improve sweet potato shelf-life. Reduction of moisture loss is achieved by refrigeration, which slows evaporation, and by storage in jacketed rooms, 'Filacell' systems or sealed boxes in cold rooms (Raghavan *et al.*, 1990), all of which increase RH around the produce However, these options are expensive to build and maintain at the retail level and yet again for sweet potato roots, which are bulky, and fetch low prices.

Recharging by submerging sweet potatoes in water to increase their turgidity and extend shelf life has not been investigated. The effects of duration of recharging on transpiration losses during subsequent storage of sweet potato have not also been determined

2.6.2 Packaging

Placing a physical barrier around the produce to reduce air movement over its surface can reduce water loss. The simplest methods cover stacks of produce with tarpaulins, or pack the produce into bags, boxes or cartons (Wills *et al.*, 1981). Close packing of produce alone restricts the passage of air around individual items and thus water loss. Even placing the produce in mesh bags can have some beneficial effect, because there is closer packing of individual items within the bags. More 'inner' fruits are created and protected from direct exposure to dry air by the outer layers in the bags (Wills *et al.*, 1981).

The degree to which the rate of water loss is reduced depends on the permeability of the package to water vapour transfer as well as on the closeness of the containment (Wills *et al.*, 1981). All materials commonly used are permeable to water vapour to some extent. Materials such as polyethylene (PE) film can be considered to be relatively good vapour barriers, because their rate of water transfer is relatively low compared to that of paper and fiberboard, which have high permeability to water vapour. Even use of paperbags or fiberboard packages substantially reduces water loss compared with unprotected, loose produce.

The ability of many packaging materials to absorb water must also be considered (Wills *et al.*, 1981). Paper derivatives, jute (hessian) bags, and natural fibers generally can absorb much water before becoming visibly damp. At the time of packing there is often a vapour pressure deficit between the produce and the package, so that water is evaporated from the produce and absorbed by the packaging material. In the cool storage of apple and pear it has been found that a 'dry' wooden box weighing 4 kilograms can

absorb about 500 grams of water at 0°C (Wills *et al.*, 1981). Packages should be equilibrated at high humidity before use, but this is considered impractical commercially. An alternative procedure is to waterproof the packaging material by incorporation of waxes or resins. Such packages are available commercially, but are necessarily more expensive than the untreated materials (Wills *et al* , 1981).

The packaging operation has many advantages, because it gives a better general appearance of freshness and turgidity is sustained longer. When packages are adequately perforated, weight loss and decay are reduced (Ceponis and Butterfield 1974). Packaging also protects the product from mechanical damage and consumer handling. During transport and marketing there is usually little humidity control available and the package may be designed to provide a partial moisture barrier.

Sweet potatoes have high moisture content, and a relatively thin and delicate skin, hence they are more prone to moisture loss. They remain metabolically active after harvest and are easily damaged, highly perishable commodity, which makes their postharvest handling and storage more difficult than that of, for example, the dry grain crops (Woolfe, 1992).

Further losses of sweet potato roots are encountered as a result of conditions during retailing. Mechanical injuries sustained by retailing in bulk in New York supermarkets produced about 5% of the unsalable roots through *Rhizopus* soft rot decay and moisture loss (Ceponis and Butterfield 1974). Rough handling sustained during retailing also caused subsequent decay due to soft rots in roots held in conditions simulating those practiced by consumers in the home. Total losses from soft rot and moisture loss during

1 week's display in bulk in a United States retail store amounted to about 13% (Ceponis *et al.*, 1973).

Packaging of roots in trays in a plastic film sleeve (open at both ends) or complete overwrapping, as a means to prevent injuries due to handling, have been used to decrease moisture losses in sweet potatoes (Woolfe, 1992). However, this treatment did not lead to reduction in soft rot. In other studies, total losses were reduced to 2.8% by impregnating the complete overwrap with a fungicide (2,6-dichloro-4-nitroaniline) (Woolfe, 1992). Losses of roots piled in heaps in tropical markets or being sold by the side of the road are likely to be much higher than those in supermarkets, but the extent of such losses has not been explored. Thus, there is need for packaging sweet potato roots to reduce these losses during retailing.

Umiecka (1980) observed the best keeping and market quality for the longest period of time (8 to 9 months) when carrots were washed in clean water, topped and tail end removed immediately after harvest; then they were placed in perforated PE bags or in crates lined with PE film, without drying in storage conditions of 0 to 11°C. For short periods of time, the carrots could be stored with good results at 4 to 5°C in unperforated bags. Similarly, use of packaging has enabled the slowing of colour development in tomato at low storage temperatures (Heinonen *et al.*, 1979). Storage of tomatoes was improved considerably when they were distributed in individual retail packages within transport crates.

Shipway (1973) tested film packs during storage of cauliflower. He observed that all the film packs reduced moisture loss. These included shrink films VF 70, VF 71, wraps RMT-68, TPF-84, non-perforated and perforated PE bags. However ventilation

was restricted too severely in the non-perforated PE bags and CO_2 accumulated to damaging levels (the curds turned grey and off-odours were produced within the bag). Perforated bags prevented this damage, but were much less attractive than the shrink film packs, which were sufficiently permeable to CO_2 to prevent an excessive build-up of the gas.

Therefore, the requirements of packaging materials include: sufficient mechanical strength to protect their contents during handling, transport and storage; no chemical contents toxic to the produce and man; weight, size and shape that meet requirements of handling and marketing for economic operations; rapid cooling of the contents; water-proofing otherwise, it can absorb water and become physically weak and enhance water loss from the produce, thus lowering it's quality; appealing to aid retail presentation, and low cost. The best and cheap sweet potato packaging material has not been determined and hence the need for this study.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Materials

3.1.1 Production site

The production site was at Kabete Field Station. The site is situated at latitude 1°15' South and longitude 36°44' East. It stands at an altitude of 1942m (Wamburi, 1973). It has an annual mean temperature of 18°C, with the mean monthly temperature varying between 14°C (in June) and 24°C (in February). The location has a bimodially distributed rain-fall, with long rains starting from late March to June and short rains from late October to December. The mean annual rainfall of the station is 1000mm (Brown and Cocheme, 1969).

The soil at the site is described as Humic nitosol with kaolinitic clay minerals, deep, well drained, dark-reddish-brown in colour, friable clay. The pH of the sub-soil ranges from 5.2 to 7.7 (Nyandat and Michieka, 1970).

3.1.2 Analytical chemicals

These were obtained through CIP (International Potato Center) and the required concentrations for analysis prepared in the laboratory. The specific weights used were obtained using a top loading balance (Model XL-1810, e=0.01, Denver Instrument Company) of range 0-1810g.

3.1.3 Packaging materials

These included perforated polyethylene, nylon gunny sack and kraft paper and were obtained from a local supermarket.

3.1.4. Potatoes

Potato genotypes 'SPK 004', 'KSP 20', 'KEMB 10', 'Yanshu' and 'Zapallo', were grown following methods used by Kenyan farmers as follows: vine cuttings were procured from the sweet potato germplasm collection plot maintained by International Potato Centre (CIP), and grown at the Field Station of the University of Nairobi, Kabete Campus, between November 1998 and June 1999- during short rains (Experiment I). The experiment was repeated between February and July 1999- during long rains (Experiment II).

The potato vines were grown in a randomized complete block design consisting of four blocks. The plots measured 7.5m X 3.0m with vines spaced at 0.30m on manually prepared ridges spaced at 0.90m apart. The vines were hand-planted. Overhead irrigation was used to supplement rainfall as needed. Weeding was carried out about four weeks after planting and the plots maintained weed free thereafter. No fertilizer application was done and neither were any pesticides applied.

The sweet potatoes were harvested eight months and six months after planting for experiment I and II, respectively. The potatoes were harvested manually by digging out from the middle two rows of each plot and their shoots removed. The roots were put in gunny bags, transported to the Crop Science Laboratory at the University of Nairobi, Kabete Campus, within 60 minutes.

3.2 Methods

3.2.1 Experimental design

In each experiment, two studies were carried out. These included: (1) Effect of recharging on moisture loss and quality changes during short-term storage of sweet

potato, (2) The effect of packaging on moisture loss and nutrient content during short-term storage of sweet potato.

To study the effect of recharging on moisture loss and quality changes of sweet potato; for each of the five sweet potato genotypes and from each experimental plot, four sweet potato roots for weight gain and loss and six roots for total soluble solids and relative solute leakage were randomly chosen. These roots were then subjected to three recharging duration treatments (0h, 7h, 14h). The design was randomized complete block design with treatments laid out in a 5x3 factorial combination.

Although five varieties were grown, only two ('Yanshu' and 'KEMB 10') were selected for the study on the effect of packaging on moisture loss and nutrient content of sweet potatoes. These genotypes were chosen on the basis of their dry matter contents as this affects their storability. 'KEMB 10', with a high dry matter content, is not suitable for storage. The opposite is true for 'Yanshu'. For each of the genotypes and from each experimental plot, four sweet potato roots for weight loss and six roots for nutrient quality analysis were selected. These were then subjected to packaging using four different package materials (open plate/ control, kraft paper, perforated polythene bag and nylon gunny bag). The design was randomized complete block design with treatments laid out in a 2x4 factorial combination.

3.2.2 Recharging of sweet potato roots

Roots used in this study were randomly selected from the lot harvested (weight range 150 to 300g). The sweet potato roots were marked before recharging, using pinned pieces of paper to allow for identification and then recharged under room conditions (23

± 2°C). Recharging was achieved by dipping the potato roots in 15 litres tap water contained in 20 litre plastic buckets at 23 ± 2°C for 0h, 7h and 14h. They were then removed from the water, drained and blotted dry with a cotton cloth, stored at 23 ± 2°C on benches and analyzed for : changes in weight, relative solute leakage and total soluble solids, initially and every 3 days during storage for 18 days.

The criteria used to justify the choice of the recharging durations tested were based on the following: times maybe appropriate for adoption for present day sweet potato industry and previous studies on recharging of carrot roots showed that recharging for more than 15 hours does not result in pronounced changes in moisture gain.

3.2.3 Packaging of the sweet potato roots

The sweet potato roots were marked and recharged in 15 litres tap water contained in 20 litre plastic buckets at 23 ± 2°C for 14 hours before packaging. For each genotype of sweet potato, four sweet potato roots for weight loss and six roots for nutrient quality analysis were pacakged in the perforated polythene package. This was replicated four times. The same was done for each genotype with the nylon gunny sack and kraft paper packages. Control roots of each genotype were placed on open plates and placed on the shelf. These were stored under room conditions (23 ± 2°C), and subjected determination of weight loss and various nutrient analyses. Measurements for weight loss were taken every 3 days during the storage period of 18 days and those for nutrient quality were obtained once every week for the three weeks storage period at room conditions.

3.3 Determination of Variables

3.3.1 Weight gain and weight loss

A top loading balance was used as previously described.

3.3.2 Relative solute leakage

Relative solute leakage of the roots was measured to determine the influence of moisture replacement on tissue permeability. Sweet potato root cores measuring 20 mm-long and 3mm-diameter from the mid section of the root were excised longitudinally using a cork borer. The cores were rinsed three times with deionised water and placed in 20 ml of distilled deionized water in 50 ml plastic jars. They were allowed to stand at room temperature (23 ± 2°C) for 24h, after which the absorbance of the dip solution was determined at 280nm using a spectrophotometer (CE 4400/UV/VIS Doublebeam Scanning Spectrophotometer, 4000 Series, Cambridge, England), to obtain its solute content. Then tissue integrity was destroyed by freezing at -85°C for 24 h. After thawing, absorbance of the bathing medium was measured to estimate the total solute content of the tissue. Relative solute leakage was calculated as the ratio of the absorbance before freezing to that after tissue disintegration by freezing.

3.3.3 Total soluble solids

Total soluble solids of the roots were measured as °Brix as follows: a root sample of approximately 5g was crushed manually and squeezed through a cheesecloth. A drop of clear solution was placed on the glass of a hand refractometer (Kruss HRN 16, W. Germany) and the °Brix measured at 20°C (A.O.A.C. 1984).

3.3.4 Dry matter content

A sample of about 100 g of fresh sweet potato root was weighed accurately and chopped into pieces of approximately 5 mm thickness with a kitchen knife. The samples were placed in an air oven at 66°C for 72h and dried to a constant weight The weight of the dry residue was expressed as percent of the original weight (Ranganna, 1977)

3.3.5 Reduced ascorbic acid

Reduced ascorbic acid content was determined by selective oxidation of ascorbic acid with a standard solution of N- bromosuccinimide (Barakat *et al.*, 1955). About 50 g of the potatoes were weighed accurately and placed in a blender together with 150 ml of 20% solution of Trichloroacetic acid. The mixture was blended at high speed for 1 minute and the filtered through Whatman No. 41 filter paper. Five milliliters of the filtrate were pipetted into a 100-ml conical flask. To this was added 5 ml of 4% Potassium Iodide followed by 1 ml starch indicator solution. The mixture was then titrated against freshly prepared 0.01% N-bromosuccinimide solution from a micro-burette to a faint blue or violet colour, which persisted for at least 15 seconds. The reduced ascorbic acid content was calculated as mg per 100g of the sample, using the following formular:

Reduced ascorbic acid in filtrate = V x C x (150÷(W x %MC of potato))/5 x 176/178

Where V is the volume of N-bromosuccinimide and C is it's concentration (mg/ml), 176/178 is the ratio of the molecular weight of ascorbic acid to that of N-bromosuccinimde, W is the weight of the sweet potato sample, MC is the moisture content in the sweet potato sample.

Losses in reduced ascorbic acid during storage were determined by obtaining the difference between measured ascorbic acid and initial ascorbic acid in each package material

3.3.6 Determination of beta-carotene content

Beta-carotene of the roots was determined using the method of Astrup *et al.* (1971) as modified by Gomez (1981) for green leafy vegetables The method involved taking 2 g of the sample and grinding with a mortar and pestle, and extracting repeatedly with small portions of acetone, until the yellow-green colour did not show up in the extract. The extracts were combined in a 100-ml round bottomed flask and evaporated to near dryness in a vacuum rotary evaporator (Heidolph,Type 51111, W. Germany) at 60°C. The residue was dissolved in about 4 ml petroleum ether (b.p. 40-60°), and quantitatively spotted on a 15 cm chromatographic column prepared as follows: about 20 g silica gel was dispersed in 15 ml petroleum ether:absolute ethanol (8:1). The slurry was slowly poured into a chromatographic column of length 30 cm and the silica gel allowed to settle and form a homogenous packing. An anhydrous sodium sulphate was added to form a 10 mm thick drying layer at the top. The eluate was collected in 25 ml volumetric flasks and made to volume with petroleum ether The absorbance of the eluate was determined in a UV-VIS spectophotometer (CE 4400 Doublebeam Scanning Spectrophotometer, England) at 450 nm.The beta-carotene concentration was determined from a standard curve prepared from pure beta-carotene solutions in petroleum spirit, and expressed as mg per 100g.

3.3.6.1 Beta-carotene standard curve

This was developed by using standard solutions of pure beta-carotene (Sigma Company, U.S.A). Solutions containing 0.4 to 2.4 beta-carotene per millilitre of petroleum spirit were prepared and their absorbance read at 450 nm, using UV-VIS spectrophotometer (CE 4400 Doublebeam Scanning Spectrophotometer, England). The absorbance values were plotted against corresponding beta-carotene concentration on a millimeter graph paper (Appendix 8).

3.3.7 Total sugars

Total sugars were determined by a colorimetric method attributed to Dubois *et al.* (1956). A sample of the sweet potato root was finely chopped. About 1g was accurately weighed and dried in an air oven at 60°C. The dried samples were then milled using a micro-miller (Type DFH, Upm 6000, Glen Creston Stanmore, England) to pass in a 0.5 mm sieve of the flour. Then 100 mg were weighed into a boiling tube, 25 to 30 ml of hot ethanol (80°C) added then mixed by vortexing. The material was left to settle for 20 to 30 minutes, then filtered through Whatman No.41 filter paper. Complete extraction of the sugars was attained by repeating the above procedure 3 to 4 times. The extract was evaporated on a hot sand bath to near dryness and the residue dispersed in about 10 ml distilled water. The mixture was quantitatively transferred into a 100-ml volumetric flask and made to 100 ml with distilled water. One millilitre of the solution and 1ml distilled water to act as blank were each placed into a labelled test-tube, and to each 1 ml of 5% phenol added and thoroughly mixed. To each test-tube were added 5 ml of 96% sulphuric acid, mixed thoroughly by vortexing and the tubes cooled to 25°C in running

tap water. A golden colour developed whose absorbance was read on a spectrophotometer (CE/4400, England) at 490nm against the blank. The concentrations of total sugars were determined as glucose equivalents from a standard curve prepared from solutions of pure glucose in distilled water.

3.3.7.1 Glucose standard curve

A glucose standard curve was developed using a concentration of between 10 to 50 μg/ml standard solutions of pure glucose (Appendix 10). The absorbance values of the standard solutions were plotted against concentration to yield a standard curve, which aided in calculation of total sugars.

3.4 Statistical analysis

In the recharging of potatoes experiment, weight gain upon recharging as well as the effect of recharging on weight loss, total soluble solids, relative solute leakage and dry matter were analyzed using a general linear model (Wilkinson *et al.*, 1992). Orthogonal polynomials were fitted using the means of various treatments for trend analysis (Steel and Torrie, 1987). Using SYSTAT software, analysis of variance was performed, and slope analysis was also performed on weight loss (% day^{-1}) to determine the rate of moisture loss during the short-term storage following recharging. For the variables total soluble solids and relative solute leakage, recharging duration × genotype × time of storage interaction was not significant. Therefore, means due to recharging duration × time of storage interaction and genotype were obtained. Mean differences among treatments were separated using the least significant difference (LSD) method.

Repeated measures analysis was done on weight gain and on weight loss data following recharging and packaging. Analysis of variance and regression analyses were also performed using the SYSTAT software (Wilkinson *et al.*, 1992). Means obtained were separated by the least significant difference (LSD) method.

CHAPTER FOUR: RESULTS

4.1 Effect of Recharging on Moisture Loss and Quality Changes During Short-term Storage of Sweet Potato

4.1.1 Weight gain and moisture loss

Weight gain increased either linearly and/or quadratically with the duration of recharging in all genotypes in both experiments (Table 1). The quadratic component showed that the increase in weight gain became less for each increment or increase in recharging duration. Most weight increment occured in, 'KEMB 10', 'SPK 004', and 'Yanshu' in both experiments. However, significant genotypic differences in weight gain were, however, not observed in experiment II. Overall, potato roots of experiment II gained more weight than those of experiment I.

A linear and/or quadratic relationship between decrease in rate of weight loss and recharging duration was observed in experiment I (Table 1). Significant differences in rate of weight loss among genotypes were not observed in experiment I. Similarly, a linear decrease in rate of weight loss and recharging duration was observed in all potatoes in experiment II. The genotypes differed in the rate of weight loss. The order of the genotypes starting with the most weight loss to the least loss was 'Yanshu', 'KEMB 10', 'KSP 20', 'SPK 004' and 'Zapallo'.

Table 1. Effect of recharging duration on weight gain during recharging and rate of moisture loss during subsequent storage at room temperatures (23 ± 2°C) of sweet potato genotypes

Genotype	Recharging (h)	Experiment I		Experiment II	
		Weight gain (%)	Weight loss(% day^{-1})	Weight gain (%)	Weight loss(% day^{-1})
'SPK 004'	0	-1.84	1.42	-2.61	1.68
	7	1.40	0.79	4.11	1.31
	14	2.48	0.79	8.76	1.08
	Trend	[z]L, Q	L	L	L
'KSP 20'	0	-1.77	1.05	-3.31	1.22
	7	0.52	0.87	4.74	0.68
	14	0.51	0.73	6.04	0.31
	Trend	L, Q	L	L, Q	L
'KEMB 10'	0	-1.71	1.31	-4.22	1.79
	7	1.89	0.72	5.64	1.33
	14	2.53	0.75	10.80	0.82
	Trend	L, Q	L, Q	L, Q	L
'Yanshu'	0	-1.92	1.12	-4.16	1.60
	7	2.69	0.71	3.23	1.01
	14	2.25	0.79	7.08	0.58
	Trend	L, Q	L, Q	L, Q	L
'Zapallo'	0	-1.58	1.34	-2.41	1.09
	7	0.80	0.73	3.40	0.74
	14	1.01	0.58	4.05	0.61
	Trend	L, Q	L, Q	L, Q	L
Recharging (R)		*	*	*	*
Genotype (G)		*	Ns	Ns	*
R X G		*	Ns	Ns	Ns
S.E		0.02	0.03	0.06	0.28

[z] L, Q, * and Ns are linear, quadratic, significant and non-significant at $P \leq 0.05$, respectively. S.E = Standard error of mean

4.1.2 Relative solute leakage

Relauve solute leakage differed with recharging duration over the storage period in both experiments (Table 2). There were no significant differences among potatoes with increase in recharging duration in all days of storage in experiment I However, relative solute leakage decreased with increase in recharging duration on the 18th day of storage. In experiment II, relative solute leakage decreased linearly with increase in recharging duration at all days of storage. Overall differences in relative solute leakage among recharging duration with increase in storage time were more pronounced in experiment II than in experiment I. Relative solute leakage increased with storage time with the control roots showing the highest increased rate followed by those recharged for 7 hours. The lowest increase in relative solute leakage over storage duration occured in potatoes recharged for 14 hours.

Genotypic differences in relative solute leakage were observed in both experiments (Figure 1). The order of genotype starting with highest to lowest relative solute leakage was "KEMB 10', 'SPK 004' and 'Yanshu', 'KSP 20' , 'Zapallo', in experiment I and 'SPK 004', 'Yanshu', 'KEMB 10', 'KSP 20', 'Zapallo', in experiment II.

Storage conditions for the 12th day of experiment I samples changed and samples were apoilt. Hence, they were not used in determination of relative solute leakage

Table 2 Effect of recharging duration and time of storage on relative solute leakage of five sweet potato genotypes

Rech. Dur. (h)	Experiment I							Experiment 2						
	Time of storage (Days)							Time of storage (Days)						
	3	6	9	12	15	18	Mean	3	6	9	12	15	18	Mean
0	44.2	42.3	40.8	-	40.9	46.1	42.7	29.4	35.2	42.3	49.1	54.5	65.3	45.9
7	30.1	43.7	42.1	-	53.9	45.8	43.1	32.2	32.6	37.3	42.5	49.0	57.2	41.8
14	28.8	47.7	40.6	-	44.1	28.8	38.0	24.6	28.8	33.5	38.8	42.5	49.5	36.3
Mean	34.3	44.5	41.2	-	46.3	40.3		28.8	32.2	37.7	43.5	48.7	57.3	
Trend	L, Q	Ns	Ns	-	Q	L, Q		L, Q	L	L	L, Q	L,Q	L	

[z]L, Q, * and Ns are linear, quadratic, significant and non significant at $P \leq 0.05$, respectively Standard error among recharging duration x storage time = 3.04 and 0.78 for experiment I and II, respectively

Rech Dur (h) = Recharging duration in hours

Note: Since recharging duration x storage time interaction was significant, the figures are averages for five sweet potato genotypes

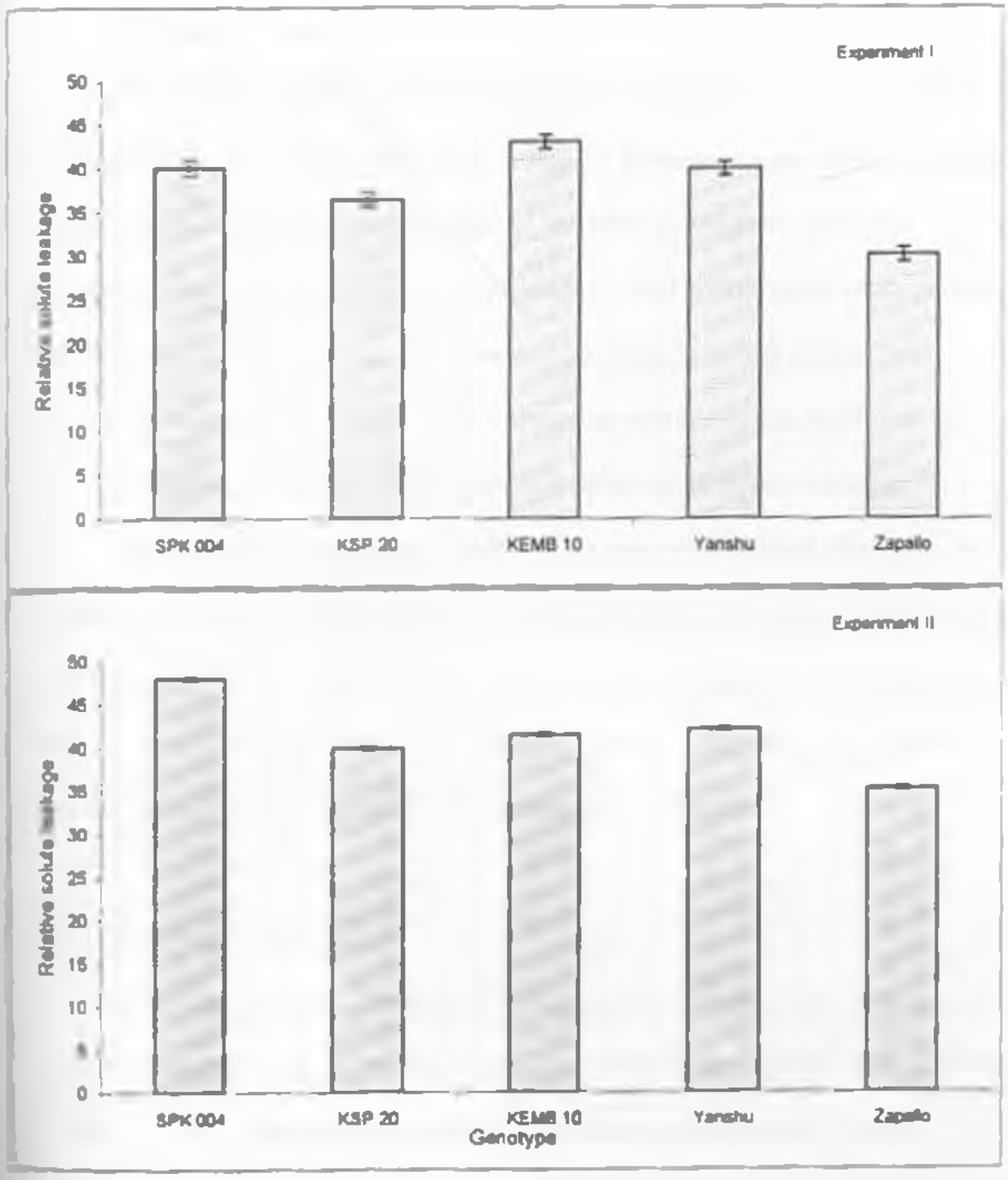

Figure 1: Relative solute leakage of sweet potato genotypes at day 18 of storage across recharging treatments

Vertical bars are LSD bars

4.1.3 Total soluble solids

Total soluble solids of the potatoes generally increased with time of storage for all recharging durations in both experiments (Table 3). However, means of the total soluble solids at the end of the 18 days in storage did not differ significantly among the treatments ; control/0h, 7h and 14h in experiment I. Total soluble solids of the potatoes generally increased with storage for all recharging durations in both experiments. Though there was a recharging duration × time of storage interaction, there were no pronounced effects of the recharging duration treatment at all times of storage.

Genotypic differences in total soluble solids were not consistent (Figure 2). In experiment I, 'KEMB 10' and 'Zapallo' had the highest total soluble solids, followed by 'Yanshu and 'SPK 004'. 'KSP 20' had the lowest total soluble solids. In experiment II, 'SPK 004' had the highest total soluble solids followed by 'KEMB 10' and 'Zapallo' then 'KSP 20'. 'Yanshu' had the lowest total soluble solid contents .

4.1.4 Dry matter content

There were no significant differences in dry matter of recharging treatments in both experiments. However, genotypic differences in dry matter content were observed (Table 4). In both experiments the order of dry matter contents from the highest to lowest was 'KEMB 10', 'SPK 004', 'KSP 20', 'Yanshu' 'Zapallo'. No significant differences in dry matter were observed between 'KEMB 10'and 'SPK 004', between 'SPK 004'and 'KSP 20'and between 'KSP 20'and 'Yanshu' in both experiments.

Table 3. Effect of recharging duration and time of storage on total soluble solids (°Brix) of five sweet potato genotypes

Rech Dur. (h)	Experiment I							Experiment 2						
	Time of storage (Days)							Time of storage (Days)						
	3	6	9	12	15	18	Mean	3	6	9	12	15	18	Mean
0	2.9	2.3	3.3	3.3	3.4	3.4	3.1	3.5	3.5	3.7	4.2	4.1	3.5	3.7
7	2.4	2.4	3.0	3.1	3.3	3.3	2.9	3.1	3.5	3.5	4.2	3.9	3.8	3.7
14	2.1	2.5	2.7	3.0	2.9	3.3	2.8	3.4	3.6	3.4	3.9	3.6	4.2	3.7
Mean	2.5	2.4	3.0	3.1	3.2	3.3		3.4	3.5	3.5	4.1	3.8	3.8	
Trend	L, Q	L	L	L	L, Q	Ns		L, Q	Ns	L	L, Q	L	L	

L and Q are significant linear and quadratic effects on recharging treatments, respectively at $P \leq 0.05$

Ns means non significant linear or qudratic effects on treatments at $P \leq 0.05$.

Rech. Dur (h) = Recharging duration in hours

Standard Error of mean among recharging duration x storage time interaction = 0.8 and 0.1 for experiment I and II, respectively.

Note: Since recharging duration x storage time interaction was significant, the figures are average for the five genotypes

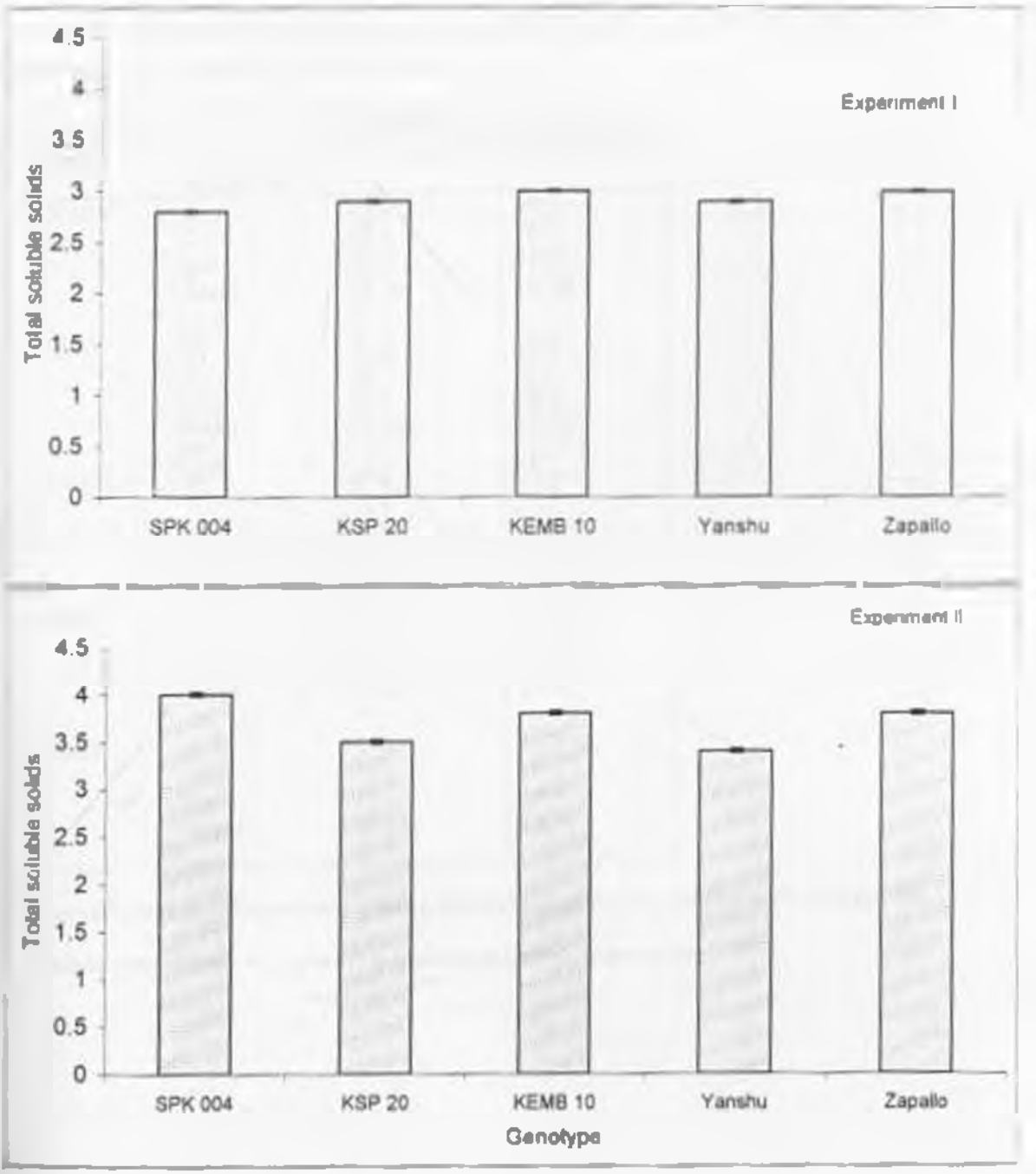

Figure 2: Total soluble solids of sweet potato genotypes at day 18 of storage across recharging treatments

Vertical bars are LSD (0.05) bars

Table 4 The effect of recharging on percent dry matter content of sweet potato genotypes at the end of 18 days storage

		Experiment 1	Experiment 2
Genotype	Recharging duration (h)	Dry matter (%)	Dry matter (%)
'SPK 004'	0	29 0	30 5
	7	28 4	29.1
	14	30 6	31 4
	Mean	29 3ab	30 3ab
'KSP 20'	0	27.8	26 8
	7	28 7	27 5
	14	27.7	28 1
	Mean	27 9bc	27 5bc
'KEMB 10'	0	33.1	34 0
	7	31.1	31 3
	14	32 5	32 9
	Mean	32 2a	32 7a
'Yanshu'	0	25.5	26 0
	7	24 4	24 9
	14	25 1	25 1
	Mean	25 0c	25 3c
'Zapallo'	0	19.9	19.7
	7	18 9	19.3
	14	18 6	19 9
	Mean	19.1d	19.7d

Means followed by different letters within a column are significantly different at P= 0.05 by LSD

Standard error of mean = 0.8 and 0 7 in experiment I and II, respectively.

4.2 Effect of Packaging on Moisture Loss and Nutrient Content of Sweet Potato

4.2.1 Weight loss

The weight loss differed among packaging materials and the genotypes (Figure 3) Weight loss was highest with the unpackaged control roots However, weight loss was not significantly different among the control, kraft paper bags and nylon gunny sack in experiment I (Figure 3) All the potatoes gained as much as 3 to 5 % of their weight upon recharging in both experiments (Figures 3) Depending on the packaging material, it took different days of storage for the potatoes to attain their original weights (before recharging); an indicator of extended storage life. For polythene packaged potatoes it took about 12 days for 'KEMB 10' in both experiments, and for 'Yanshu' about 18 and 12 days for experiment I and II, respectively For kraft paper bag and nylon sack packaged potatoes, it took between 3 and 5 days to reach their original weights in both experiments. The control took the shortest time, between 2 and 4 days to reach pre-recharged weights in both experiments More distinct differences among packages were observed in experiment II (Figure 3), where the control roots lost significantly more weight than the packaged roots In both experiments, roots in perforated polythene package lost the least weight

There were no significant differences in weight loss between genotypes up to the 9th day, but 'KEMB 10' had slightly higher weight loss than 'Yanshu'in all packages in both experiments Generally, experiment II potatoes lost slightly more weight than experiment I potatoes

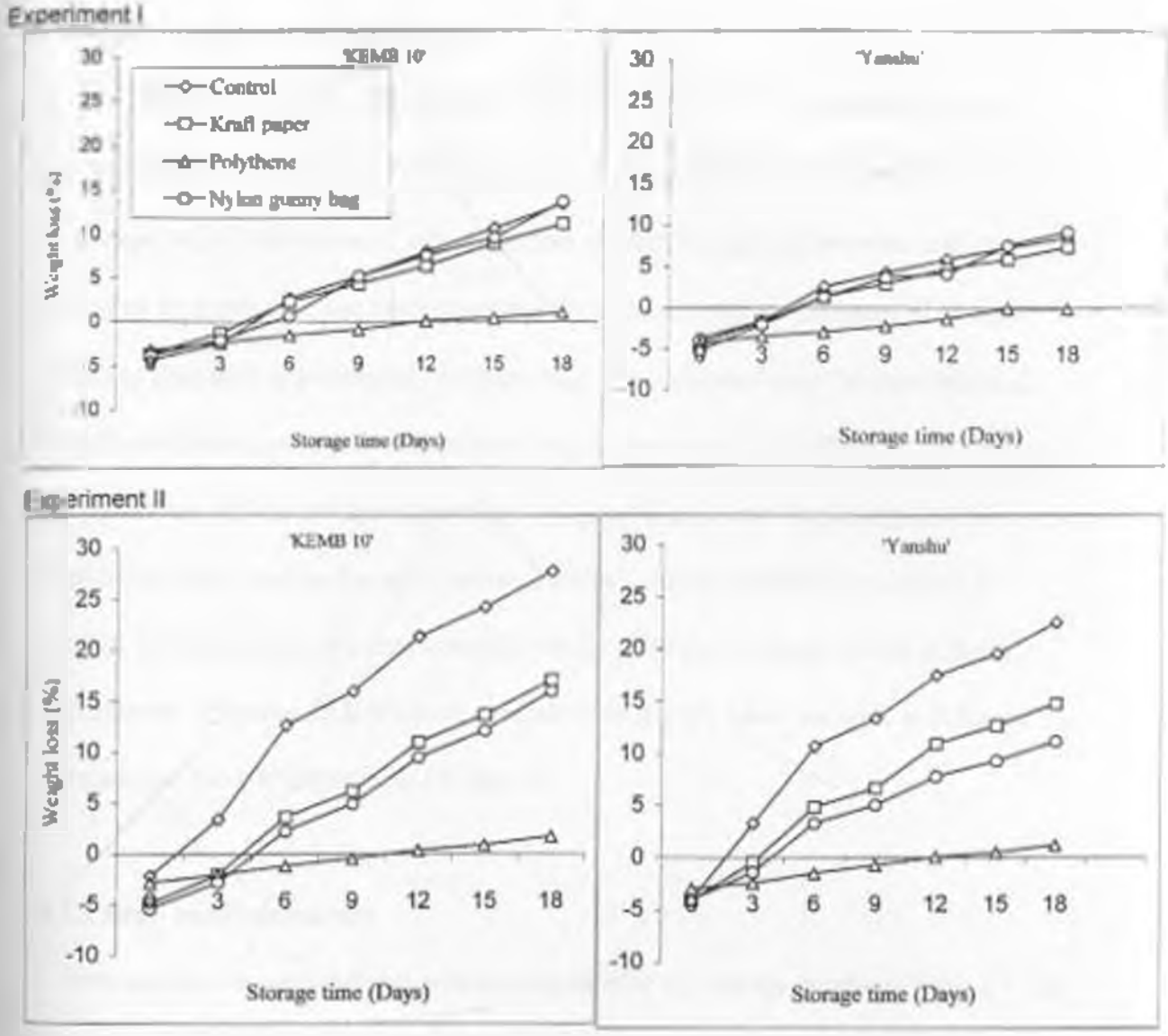

Figure 3: Effect of packaging material on percent weight loss of two sweet potato genotypes in experiment I and II.

4.2.2 Reduced ascorbic acid content

Reduced ascorbic acid contents differed among different treatments over the storage period (Table 5). In experiment I, there was significant package type × genotype × storage period interaction. Control potatoes showed the highest ascorbic acid loss followed by nylon sack and kraft paper bag for both genotypes at all times of storage. Potatoes packaged in perforated polythene bags had the lowest loss. In experiment II, significant losses in ascorbic acid occured only in the control of 'KEMB 10'. There were no significant differences among packages in ascorbic acid loss. Packaging had no significant effect on ascorbic acid loss in 'Yanshu'. All the treatments exhibited a general decrease in ascorbic acid content over the three week storage period in both experiments. Experiment II potatoes generally had slightly lower ascorbic acid losses compared to those of experiment I (Table 5).

4.2.3 Beta- carotene content

Beta-carotene content differed with treatments over the storage duration (Table 6). In experiment I, there was significant packaging material × genotype × storage period interaction. The highest beta- carotene content was observed in perforated polythene bags at all times of storage. During week II of storage, the order of package effect on retention of beta-carotene from highest was perforated polythene, nylon sack, kraft paper, and control for 'KEMB 10'. However, for 'Yanshu', the order was perforated polythene, kraft paper, nylon sack, and control. During week III, the order was perforated polythene, nylon sack, kraft paper, and control for 'KEMB 10', and perforated polythene, nylon sack, control, and kraft paper for 'Yanshu'.

Table 5. Effect of packaging material and storage time on the loss of ascorbic acid (%) of 'KEMB 10' and 'Yanshu' genotypes of sweet potato during storage

		Experiment I				Experiment II			
Genotype	Package material	Storage time (weeks)				Storage time (weeks)			
		1	2	3	Mean	1	2	3	Mean
'KEMB 10'	Open plate (Control)	20.2a	34.3a	44.8a	24.8	4.2	12.0	21.8	9.5a
	Kraft paper	12.2bc	24.7c	36.5b	18.3	6.1	6.3	5.3	4.4b
	Perforated polythene	6.3c	12.5e	20.5e	9.8	3.7	2.1	3.4	2.3b
	Nylon sack	14.6b	25.8c	38.3b	19.7	3.4	8.7	6.5	4.6b
	Mean	13.3	24.3	35.0		4.4a	7.3a	9.2a	
'Yanshu'	Open plate (Control)	19.3a	33.2a	44.4a	24.2	4.2	6.1	14.7	6.2a
	Kraft paper	12.9b	23.9c	32.5c	17.3	4.9	6.1	7.4	4.6a
	Perforated polythene	9.0c	18.4d	25.0d	13.1	3.8	4.6	9.1	4.4a
	Nylon sack	18.8a	29.8b	37.6b	21.5	5.3	9.1	5.1	4.9a
	Mean	15.0	26.3	34.9		4.6a	6.5a	9.1a	

The initial ascorbic acid content of potatoes 'KEMB 10' = 21.5mg/100g, 'Yanshu' = 23.3 mg/100g in experiment I and 'KEMB 10' = 14.3 mg/100g , 'Yanshu' = 14.8 mg/100g in experiment II.

Means within followed by different letters a column and/or row are significantly different at $P \leq 0.05$

Standard error of mean among the package materials = 1.5 and 1.7 for experiment I and II, respectively.

Table 6. Effect of type of package on beta-carotene content (mg/100g) of 'KEMB 10' and 'Yanshu' genotypes of sweet potato during storage

Genotype	Package material	Experiment I					Experiment II				
		Storage time (weeks)					Storage time (weeks)				
		0	1	2	3	Mean	0	1	2	3	Mean
'KEMB 10'	Open plate (Control)	3.8a	4.6c	4.9dc	5.4c	4.7	2.1	1.8	2.1	2.0	2.0c
	Kraft paper	3.8a	4.7c	7.6a	11.8a	7.0	2.1	2.2	3.8	3.4	2.9b
	Perforated polythene	3.8a	7.5a	7.5a	12.1a	7.8	2.1	2.8	4.5	4.9	3.5a
	Nylon sack	3.8a	6.4b	6.3b	8.3b	6.2	2.1	2.4	4.3	3.8	3.1ab
	Mean	3.8	5.9	6.6	9.4		2.1a	2.3a	3.7a	3.5a	
'Yanshu'	Open plate (Control)	0.5b	0.5g	0.7g	0.7f	0.6	0.6	0.8	1.1	1.1	0.9d
	Kraft paper	0.5b	1.9e	1.9e	0.6f	1.3	0.6	0.8	1.6	2.1	1.3c
	Perforated polythene	0.5b	2.4d	2.8d	3.5d	2.3	0.6	0.8	2.8	4.0	2.0a
	Nylon sack	0.5b	0.9f	1.6f	1.9e	1.2	0.6	0.7	2.7	3.5	1.9b
	Mean	0.5	1.4	1.8	1.7		0.6b	0.8b	2.0b	2.7b	

Means followed by different letters within a column and/or row within a column and/or row are significantly different at $P \leq 0.05$ by LSD

Standard error of mean among the package materials = 0.2 and 0.3 in experiment I and II, respectively

In experiment II, there was no significant packaging material × genotype × storage period interaction. Beta- carotene content differed with packaging materials. Perforated polythene followed by nylon sack had the highest, followed by kraft paper bag and the least beta- carotene was in the control for 'KEMB 10'. For 'Yanshu', potatoes in perforated polythene bag followed by those in nylon gunny sack had the highest beta-carotene contents followed by those in kraft paper bag and the control.

Genotypic differences were observed in beta-carotene content (Table 6). 'KEMB 10' had a higher value than 'Yanshu' in both experiments. Generally, beta-carotene contentn increased with storage in both experiments.

4.2.4 Total sugars

Total sugars differed with packaging materials across the storage duration (Table 7). In experiment I of both genotypes, the roots differed in total sugar content (%). The order of effect of package on total sugar content from the highest to the lowest was perforated polythene, nylon sack, kraft paper. The unpackaged/ control roots had the lowest total sugars. However, in experiment II of both genotypes, perforated polythene and kraft paper-packaged potatoes had the highest sugar content (%). In constrast, nylon sack and control had the lowest. No significant differences in sugar content were observed between perforated polythene and kraft paper and also between nylon sack and control.

Genotypic differences in total sugars were only observed in experiment I, where 'KEMB 10' had a higher value than 'Yanshu'. In experiment II, no significant genotypic differences were observed. In general, total sugars increased with storage time in both experiments (Table 7).

Table 7 Effect of type of package on percent total sugars of 'KEMB 10' and 'Yanshu' genotypes of sweet potato during storage

Genotype	Package material	Experiment I					Experiment II				
		Storage time (weeks)					Storage time (weeks)				
		0	1	2	3	Mean	0	1	2	3	Mean
'KEMB 10'	Open plate (Control)	2 2	2 3	4 0	5 3	3 4d	2 1	1 7	2 8	4 0	2 7b
	Kraft paper	2 2	2 9	4 6	5.3	3.7c	2 1	2.4	4 8	6 2	3 9a
	Perforated polythene	2 2	3 5	5 7	6 8	4.5a	2 1	3 3	5 2	5 8	4 1a
	Nylon sack	2 2	3.0	5 0	6.2	4 1b	2 1	2.0	3 7	4 8	3 2b
	Mean	2.2a	2 9a	4.8a	5.9a		2.1a	2 4a	4 1a	5 2a	
'Yanshu'	Open Plate (Control)	1.9	1 7	2.9	4.3	2.7d	2 0	2.7	3 5	4.7	3.2b
	Kraft paper	1.9	2 0	3.5	4.8	3 0c	2 0	3 9	5 0	5 6	4 1a
	Perforated polythene	1.9	2 6	4.0	5 6	3.5a	2.0	3 5	5 6	6 4	4 4a
	Nylon sack	1.9	2 1	3.6	5.0	3.1b	2 0	2 8	4.5	5.3	3 7b
	Mean	1.9b	2.1b	3.5b	4.9b		2 0a	3.2a	4 6a	5 5a	

Means followed by different letters within a column and/or row are significantly different at $P \leq 0.05$

Standard Error of the mean among package materials = 0 1 and 0 4 in experiment I and II, respectively

4.2.5 Total soluble solids

There were no significant differences among the different packaging materials in both experiments (Table 8). Total soluble solids increased with storage time in both experiments. Genotypic differences in total soluble solid content were not consistent with storage under various packages.

Table 8. Effect of type of package on total soluble solids (°brix) of 'KEMB 10' and 'Yanshu' genotypes of sweet potato during storage

Genotype	Package material	Experiment I					Experiment II				
		Storage time (weeks)					Storage time (weeks)				
		0	1	2	3	Mean	0	1	2	3	Mean
'KEMB 10'	Open plate (Control)	2.9	2.7	3.3	3.4	3.0a	3.4	2.8	3.1	4.2	3.1a
	Kraft paper	2.9	2.9	3.2	3.3	3.1a	3.4	2.8	3.3	3.5	3.2a
	Perforated polythene	2.9	2.8	3.5	3.6	3.2a	3.4	3.5	3.2	3.7	3.5a
	Nylon sack	2.9	3.1	3.1	3.6	3.2a	3.4	2.8	3.3	3.7	3.3a
	Mean	2.9a	2.8b	3.2a	3.5a		3.4a	3.0b	3.2b	3.8a	
'Yanshu'	Open plate (Control)	1.9	2.9	3.2	3.3	2.8a	3.5	3.1	3.9	3.3	3.1a
	Kraft paper	1.9	3.1	3.3	3.3	2.9a	3.5	3.0	3.0	4.0	3.4a
	Perforated polythene	1.9	3.4	3.4	3.5	3.0a	3.5	3.6	3.5	3.9	3.6a
	Nylon sack	1.9	3.2	3.2	3.4	2.9a	3.5	2.9	3.4	2.9	3.2a
	Mean	1.9a	3.1a	3.3a	3.4b		3.5a	3.1a	3.5a	3.5a	

Means followed by different letters within a column and/or row are significantly different by LSD, $P < 0.05$

Standard Error of mean among the package materials = 0.2 , in both experiments

CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Effect of Recharging on Moisture Loss and Quality During Short-term Storage of Sweet Potatoes

The edible portion of sweet potato contains an average of 70% moisture (Woolfe, 1992). Succulent products have high moisture content at harvest, and the loss of even a relatively small amount of water can have a serious effect on weight (economic), nutritional, physiological, physical, pathological and aesthetic losses (Kays, 1991). The quality of fresh produce may, hence, be maintained if the above changes were either slowed down or reversed. The question behind this study was: can recharging alone or combined with appropriate packaging extend shelf-life of sweet potato roots so as to reduce losses and facilitate transport and marketing for vendors in need of quick money and so do not need to store their sweet potato harvest for long periods and do not have adequate time to carry out curing of the roots? In postharvest handling of plant organs (e.g. sweet potato roots), maintaining cell turgidity is the prime factor for successful preservation of quality (Weichmann, 1987). The option of recharging (replacement of water) to maintain the quality of sweet potato roots has not been explored. In this study, an increase in recharging duration not only led to water absorption, hence weight gain, but it also led to a reduction in quality loss as shown by the decrease in both relative solute leakage and total soluble solid content.

Storage under high humidity reduces moisture loss and maintains turgidity of horticultural produce (van den Berg, 1987). Recharging by dipping produce in water increases turgidity, making longer storage possible. Shibairo (1998) in a study with carrots reported that recharging could replace most of the lost moisture during short-term

postharvest storage. In the study, the carrots which had lost 2.96% of their weight regained most of it (2.45%) during recharging for 12 h. One other possible benefit of recharging may be reduced rates of moisture loss during subsequent storage. In this study, an increase in recharging led to a decreased rate of moisture loss from sweet potato roots during short-term storage. These results do not agree with those of Shibairo (1998), who did not observe any change in subsequent moisture loss upon storage in carrots. It is, therefore, deduced that recharging will benefit sweet potatoes through replacement of the lost moisture and reduced subsequent moisture loss rate. In this study, a recharging duration of 14h led to most weight increments in genotypes 'KEMB 10', 'SPK 004' and 'Yanshu' followed by 'KSP 20' and 'Zapallo'; in that order. This in turn led to an increase of shelf-life of the sweet potatoes. 'KEMB 10' is known to have poor storability, thus not suitable for storage and for transport over long distances, due to its high dry matter content hence poor wound healing ability (Quirien van Oirschot 1998). 'KEMB 10' gained 10.8% of mass upon recharging for 14h (Table 1). These potatoes were losing their weight at a rate of 0.82% per day, implying they would take 13.2 days to lose the gained weight upon recharging. Hence, recharging had improved shelf-life by at least 13 days.

During the postharvest period, there are a number of potential stresses to which the plant material may be exposed. Among these is water stress (Kays, 1991). Perishable plant products respond differently to stresses caused during postharvest time. One effect of such stresses would be a change in membrane permeability and hence integrity. Relative solute leakage has been used as an indicator of membrane integrity (Pooviah and Leopold, 1976; Toivonen, 1992). In this study, recharging treatments were used to

attempt to lower water stress levels in sweet potato roots during the postharvest period. The results showed that relative solute leakage significantly decreased linearly with increase in recharging duration only in experiment II potatoes (Table 2, Appendix 2). The results further showed that relative solute leakage generally increased in all potatoes during the storage time (Table 2). However, the rate of increase in relative solute leakage was most in the control and least in the potatoes recharged for the longest duration (14h) for all the genotypes. This suggests that recharged roots were less stressed, hence there components of quality were maintained, compared to the non-recharged ones during postharvest storage.

Many handling and storage techniques have been designed to retard the rate of development of senescence in postharvest products. Refrigeration has been extensively used to reduce moisture loss and slow metabolism, whereas use of jacketed room storage and "Filacell" systems increase relative humidity, which reduces moisture loss (Raghavan *et al* .,1990). However, these systems are too expensive for a farmer and thus not appropriate for retail market. This study demonstrated that senescence may be retarded through replacement of lost moisture.

The results of this experiment showed that relative solute leakage differed among genotypes. 'SPK 004' was among the genotypes with the highest relative solute leakage in both experiments, while 'Zapallo' had the lowest relative solute leakage. Differences among genotypes in relative solute leakage, hence membrane integrity, may be due to the differences in the fatty acid composition in the bilipid layer inherent amongst genotypes. Salisbury and Ross (1991) have shown that differences in membrane permeabilty vary among genotypes.

The general increase in total soluble solids which takes place during storage of sweet potato roots is as a result of metabolic activity (Woolfe, 1992) Kays (1991) suggested that metabolic control increases the length of time a product can effectively maintain its existing position. In this study, recharging had no significant effects on total soluble solid content. This suggested that recharging does not extend sweet potato shelf-life through changing the metabolic activities involved in total soluble solid increase It has been observed that there are differences in the way cultivars respond to storage conditions that affect the extent of starch conversion to soluble solids. (Walter *et al.*, 1975) reported that α-amylase activity increased most during storage in the classified as 'moist' cultivars and least in the 'dry' cultivars. It is, therefore, possible that the effects of α-amylase on turning starch to simple sugars is genotypically dependent. However, in this study, there were no consistent genotypic differences in the two experiments. Exactly why genotypic variations were observed in the two experiments was not determined.

Approximately 80 to 90% of the sweet potato dry matter (24 to 27% fresh weight) is made up of carbohydrates, which consist mainly of starch, with lesser amounts of pectins, hemicelluloses and cellulose. The relative composition varies not only with cultivars and maturity of the root, but also with storage time and cooking or processing (Woolfe, 1992). In this study, dry matter content of the sweet potato was not significantly affected by the recharging treatments. However, dry matter varied significantly among genotypes, with the order from the highest to the lowest as follows: 'KEMB 10', 'SPK 004', 'KSP 20', 'Yanshu', 'Zapallo'. Quirien van Oirschot (1998) reported that the cultivars with a low dry matter content had better wound healing

abilities, and hence showed low postharvest weight loss through moisture loss. Conversely, cultivars with a high dry matter content had poor wound healing ability, hence more postharvest moisture loss. It is possible 'KEMB 10' and 'SPK 004' genotypes with high dry matter contents had poor wound healing abilities, hence showed relatively higher weight losses and poor storability in this study.

Planting as well as harvesting dates differed in the two experiments carried out. Experiment I and II crop were harvested after eight and six months, respectively. Hence, experiment I roots were older than those of experiment II. Variations in maturity can possibly affect the extent of suberization in the roots. Older roots have more suberin, which decreases the rate of moisture uptake and loss of the roots (Burton, 1982). This may explain the differences observed in the trends of the variables studied as affected by the recharging treaments in the two experiments. This can be verified using roots of the same age.

5.2 The Effect of Packaging on the Shelf-life of Sweet Potato

One of the ways by which evaporative loss from commodities can be minimized, hence quality losses minimized, is by placing a physical barrier around the produce to reduce air movement across its surface (Wills *et al.*, 1981). Such a barrier includes the use of packages. While packaging is required to fulfill a number of different functions, its primary role is to retard or prevent loss of quality (nutritional and aesthetic) and to give protection against enviromental contamination. Packaging also reduces the rate of cooling by restricting air movement around the individual items, hence the need to perforate packages to allow escape of respiratory heat and gaseous exchange (Wills *et*

al., 1981). Packages differ in the rate of water and air permeability, which leads to the differences in the rate of moisture and quality loss.

Before packaging all the sweet potato roots were recharged for 14h, recharging duration that proved to be the most beneficial of those tested in the above study. In this study, roots packaged in perforated polythene bags showed the least moisture and weight loss, least loss in ascorbic acid content, highest beta-carotene content, and highest total sugars. The kraft paper bag and nylon gunny sack packaged roots did not have consistent ranks in the variables studied. The effects of packaging material in roots packaged in kraft paper bag and nylon gunny sack were not significantly different. However, they showed lower moisture, weight losses and ascorbic acid loss, higher total sugars and beta-carotene content than the control or non-packaged sweet potato roots. The unpackaged/ control sweet potato roots almost always showed the highest loss of all the variables determined. Total soluble solids was not significantly affected by the packaging material.

The degree to which the rate of water loss is reduced is dependent on the permeability of the package to water vapour transfer as well as the closeness of the containment. Materials such as polythene film can be considered to be relatively good vapour barriers, because their rate of water transfer is relatively low (Wills *et al.*, 1981). This was confirmed in this study as the roots packaged in perforated polythene bags showed the least weight loss. Kraft paper bag has higher permeability to water vapour compared to polythene film. Paper derivatives have been known to absorb much water before becoming visibly damp, creating a higher WVPD, hence more movement of moisture from the produce to the enviroment (Wills *et al.*, 1981). Such absorption could

have occured in the kraft paper bag package, hence leading to more increased moisture and weight loss by the roots packaged in it. The nylon gunny sacks also led to more water loss probably due to a lot of perforations they have, thus allowing excessive air movement around the produce (Wills *et al.*, 1981). Even the use of paper bags and sacks will substantially reduce water loss compared with unprotected loose produce as shown by the unpackaged/control roots having the highest moisture loss in this study.

In this study, pronounced genetic differences were observed in experiment II, where 'KEMB 10' lost more weight than 'Yanshu'. In contrast, less pronounced genotypic variations in weight loss were observed in experiment I. One factor that can cause differences in weight loss among root plants is root suberization (or lignification) that may occur due to age. Genetic variations in response to root suberization (or lignification) have been reported (Gull and Duarte, 1974). Quirien van Oirschot (1998) reported that lignification index (number of roots that lignified/total number of roots) varied among sweet potato genotypes. The amount of lignification in experiment I potatoes may have been too high, and hence masked the variations in postharvest moisture loss due to packaging. Experiment II potatoes could have been less lignified and thus the packaging treatments imposed showed variations.

Combination of recharging and packaging significantly improved the shelf-life of the sweet potatoes. Recharging replaced the lost moisture from the roots and packaging could have maintained a relatively high relative humidity around the roots. Quirien van Oirschot (1998) reported that lignification index was related to dry matter and relative humidity. There is a critical moisture level below which lignification does not occur. This is why roots with high dry matter content e.g. 'KEMB 10' do not heal

their wounds as easily; they dry out too quickly, and reach the critical moisture content more rapidly.

The concentration of ascorbic acid declines fairly rapidly in many of the more perishable fruits and vegetables after harvest (Kays, 1991). Hence, losses are greater with increasing storage duration. In this study, despite packaging, ascorbic acid content in sweet potato roots decreased with storage. The loss was greatest in the control roots and least in the roots packaged in perforated polythene bags. Other workers have found that ascorbic acid content of sweet potato decreases significantly during storage. Extremely high true losses of ascorbic acid, being 70% of the original value at one location, have been observed in potato roots that experienced very high levels of shrinkage due to uncontrolled humidity (Speirs *et al.*, 1953). Among the packages utilized in this study, the perforated polythene bag-packaged roots had the lowest rate of water transfer, thus lost the least water and weight. These roots also had the highest ascorbic acid content due to the least loss during the storage period. Of the other packages used, kraft paper bag-packaged roots showed a lower loss of ascorbic acid than roots packaged in nylon gunny sack, which has excess perforations that allow more water transfer from the roots. The unprotected roots (control) lost the most ascorbic acid. It is, therefore, apparent that packaging material that favours moisture loss, hence commodity shrinkage also favours ascorbic acid loss. In contrast, less ascorbic acid is lost when commodity is packaged in materials leading to less moisture loss.

Genetic differences in ascorbic acid losses during storage have been reported (Woolfe, 1992). There was an indication that the cultivars with the highest initial ascorbic acid content experienced the greatest percent losses during storage (Speirs *et al.*,

1953). In this study, however no pronounced genotypic differences were observed in both experiments.

Beta-carotene is a provitamin A compound. Vitamin A deficiency is one of the major public health problems, which parts of the developing world are presently facing (Woolfe, 1992). It is the main cause of child blindness, and even in its acute forms, vitamin A deficiency hinders normal growth and development and lowers resisitance to infection, hence a very important nutrient component of foods. One of the major contributions which sweet potatoes could make to the health and welfare of humankind, however, is that of supplying caroteinoid vitamin A precursors.

The increase in carotenoid pigments in sweet potato roots during storage has been shown to be primarily due to an increase in beta-carotene (Yamatoto and Tomita, 1958). More studies confirms that carotenoids are not lost during storage and that they may even increase (Picha, 1985). It has been suggested that beta-carotene is both synthesized and degraded in the roots during storage and that a true increase depends upon the rate of enzymically controlled synthesis being greater than degradation (Yamatoto and Tomita, 1958). In this study, beta-carotene increased during storage in both the packaged and unpackaged sweet potato roots. However, the increase was highest in the roots packaged in perforated polythene bags and least in the unprotected roots/control. Kraft paper bag and nylon gunny sack packaged roots were intermediate in beta-carotene contents, with their ranking interchanging in the two experiments that were carried out (Table 6). The package that allowed the least water transfer, perforated polythene bag, from the commodity allowed a greater net synthesis of beta-carotene. In contrast, little beta-carotene synthesis occurred when the commodity was packaged in

materials leading to more moisture loss while, the lowest synthesis occurred in the unprotected roots/ control.

The mechanism for carotenoid synthesis appears to be a genetic factor either present or absent in a root. Woolfe (1992) reported that the major factor influencing total carotenoid content (and thereby beta-carotene) is the cultivar. Cultivars with the highest beta-carotene content at harvest also have the highest content at any stage during storage (Ezell and Wilcox, 1958, Yamamoto and Tomita, 1958). Genotypic differences were observed in beta-carotene content in this study. 'KEMB 10' showed higher beta-carotene in both experiments during all weeks of storage.

The major sugars occurring in raw sweet potato roots are sucrose, glucose and fructose. Sugar content increase and starch content decreases significantly due to the activity of α-amylase (Walter *et al.*, 1975). Freshly harvested sweet potato roots contain relatively little α-amylase, but the level increases greatly during storage (Walter et al., 1975). In this study, total sugars increased with storage in both the packaged and control roots. Highest increase in total sugars occured in roots packaged in perforated polythene bags. Roots packaged in nylon gunny sack, kraft paper bag and control showed lower increases in sugar content (Table 7). Bushuk and Lee (1978) stated that total sugar content normally increased in potatoes with high moisture content during storage Pixton and Hill (1967) observed a loss in total sugar content in potatoes with low moisture contents under optimum storage conditions. In this study, an increase in total sugars in perforated polythene-packaged roots, may have occured due to increases in respiration mainly due to the high moisture content. Nylon gunny sack, kraft paper and control have higher capabilities of moisture transfer, hence showed lower sugar contents. However,

significant differences in total soluble solids were not observed among the different packages in this study. Total sugars contribute to total soluble solids (Kays, 1991). It is possible that a change in total sugars due to packaging was not significant to cause a change in total soluble solids in this study.

There are significant differences in the way cultivars respond to storage, which affects the extent of starch conversion to sugars and dextrins (Walter *et al.*, 1975). In this study, genotypic differences in percent total sugars were only observed in experiment I, where 'KEMB 10' had a higher value than 'Yanshu'. In experiment II, no significant genotypic differences were observed. Time of harvest had a significant effect on total sugar content in six cultivars grown in one location in Brazil (Menezes *et al.*, 1976). Experiment I potatoes were harvested much latter than those of experiment II. It is therefore, apparent that genotypic differences in total sugars is more pronounced in the older sweet potato roots.

5.3 Conclusions

The study showed that recharging can extend the shelf-life of sweet potato roots by allowing the replacement of lost moisture, hence keeping them fresh longer without significantly altering their quality. Weight loss is an important measure for root deterioration and, hence, storability. Thus, recharging would improve the storability of sweet potato roots, hence improve its shelf-life. It was observed that a significant linear relationship existed for the recharging duration treaments. Recharging for 14h allowed roots to keep longer by gaining the and most water, hence turgidity was maintained longer and by lowering relative solute leakage compared to 7h recharging duration and the non-recharged roots. Fouteen hour recharging duration would be adequate to gain

sufficient extention of shelf-life. Recharging should, therefore, be explored as an option of improving sweet potato short-term storage during retailing

These studies also showed that packaging can extend the shelf life of sweet potato roots without significantly altering their quality. Perforated polythene bag allowed for the most nutrient retention as well as prevented the most moisture loss compared to the other packages tested (nylon gunny sack, kraft paper bag and open plate control) Similarily, kraft paper bag and nylon gunny sack resulted in lower weight loss and some nutrient retention. However, pronounced differences in effects of kraft paper bag and nylon gunny sack in the variables studied were not observed. The study also revealed that any form of packaging is better, because the control sweet potato roots always exhibited the highest loss in the variables determined. Total soluble solid content of the roots was not significantly affected by packaging. Hence, perforated polythene bags should be explored as a packaging option for improving short-term storage of recharged sweet potato roots during retail marketing.

5.4 Recommendations

To extend the shelf-life of sweet potato roots, thereby reduce postharvest losses due to moisture loss and to facilitate transport and marketing of the roots for fast cash markets, recharging combined with packaging using perforated polythene need to be applied on the roots. However, further studies need to be carried out to obtain the optimum recharging duration of sweet potato roots.

There is need to establish how long sweet potato roots can remain fresh after recharging and if the physical and chemical properties of water would influence recharging.

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APPENDICES

Appendix 1. Analysis of variance for weight gain and weight loss as affected by recharging treatments.

		Experiment I		Experiment II	
		weight gain	weight loss	weight gain	weight loss
SOURCE	DF	M-square	M-square	M-square	M-square
R	3	0.044	0.146	13.356	0.154
V	4	14.012*	0.224	46.895	3.683*
T	2	299.124*	5.556*	2415.924*	12.457*
V X T	8	5.945*	0.162	43.360	0.238
Ex. Error	42	1.375	0.179	30.36	0.379
Sp. Error	217	1.124	0.146	21.691	0.198

R- replication, T- recharging duration , V- genotype, X- interaction ,*- significance at P ≤ 0.05, DF- degrees of freedom, M-square- Mean square Ex. Error- Experimental error and Sp. Error- Sampling error.

Appendix 2. Analysis of variance table for relative solute leakage of sweet potato genotypes as affected by recharging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	542.833	74.158
T	2	136.625	2822.466*
V	4	1710.447*	1517.213*
D	5	5190.337*	6833.617*
T X V	8	484.689	55.955
T X D	10	1127.637*	115.137*
V X D	20	665.723	78.492
T X V X D	40	549.406	27.961
Error	267	556.615	44.071

R- replication, T- recharging duration, V- genotype, D- days, X- interaction, DF- degrees of freedom, M-square- Mean square and *- significance at P ≤ 0.05.

Appendix 3. Analysis of variance table for total soluble solids of sweet potato genotypes as affected by recharging treatments

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	0.937	0.925
T	2	3.323*	0.173
V	4	0.944*	3.496*
D	5	0.895*	4.455*
T X V	8	0.213	0.170
T X D	10	0.707*	1.086*
V X D	20	0.110	0.303
T X V X D	40	0.185	0.127
Error	267	0.116	0.197

R- replication, T- recharging duration, V- genotype, D- days, X- interaction, DF- degrees of freedom, M-square- Mean square and *- significance at $P \leq 0.05$.

Appendix 4. Analysis of variance table for percent dry matter of sweet potato genotypes as affected by recharging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	8.244	3.930
T	2	12.422	28.071
V	4	1186.591***	1210.232***
T X V	8	11.322	8.855
R X TR	42	12.728	13.023
Error	180	10.232	7.510

R- replication, T- recharging duration, V- genotype, X- interaction, DF- Degrees of freedom, M-square- mean square and *- significance at $P \leq 0.05$.

Appendix 5. Univariate and Multivariate repeated measures analysis for weight gain and weight loss as affected by packaging treatments.

		Experiment I	Experiment II
Between subjects			
SOURCE	DF	M-square	M-square
R	3	282.032	128.326
V	1	325.454	60.005
T	3	1591.281*	8296.931*
V X T	3	22.364	12.868
R X V	3	84.025	258.602
R X T	9	112.752	239.915
R X V X T	9	95.160	149.571
Error	95	83.84	77.692
Within subjects			
D	6	2433.515*	5281.486*
D X R	18	6.526	66.814
D X V	6	47.546*	407.620*
D X T	18	121.591*	8.954*
D X V X T	18	8.890	15.078
D X R X V	18	5.354	10.036
D X R X T	54	3.608	9.058
D X R X VX T	54	6.331	6.102
Error	570	5 090	

R- replication, T- recharging duration, V- genotype, D- storage days, X- interaction ,* significance at $P \leq 0.05$, DF- degrees of freedom, M-square- Mean square.

Appendix 6 Analysis of variance table for percent loss of ascorbic acid of sweet potato genotypes as affected by packaging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	192.032	33.174
T	3	1934.644*	233.963*
V	1	49.210	2.241
D	3	14468.679*	979.078*
T X V	3	65.345	84.058
T X D	9	260.282*	153.995*
V X D	3	19.891	2.802
T X V X D	9	16.932	36.123
Experimental Error	93	43.069	40.301
Sampling Error	221	19.063	23.495

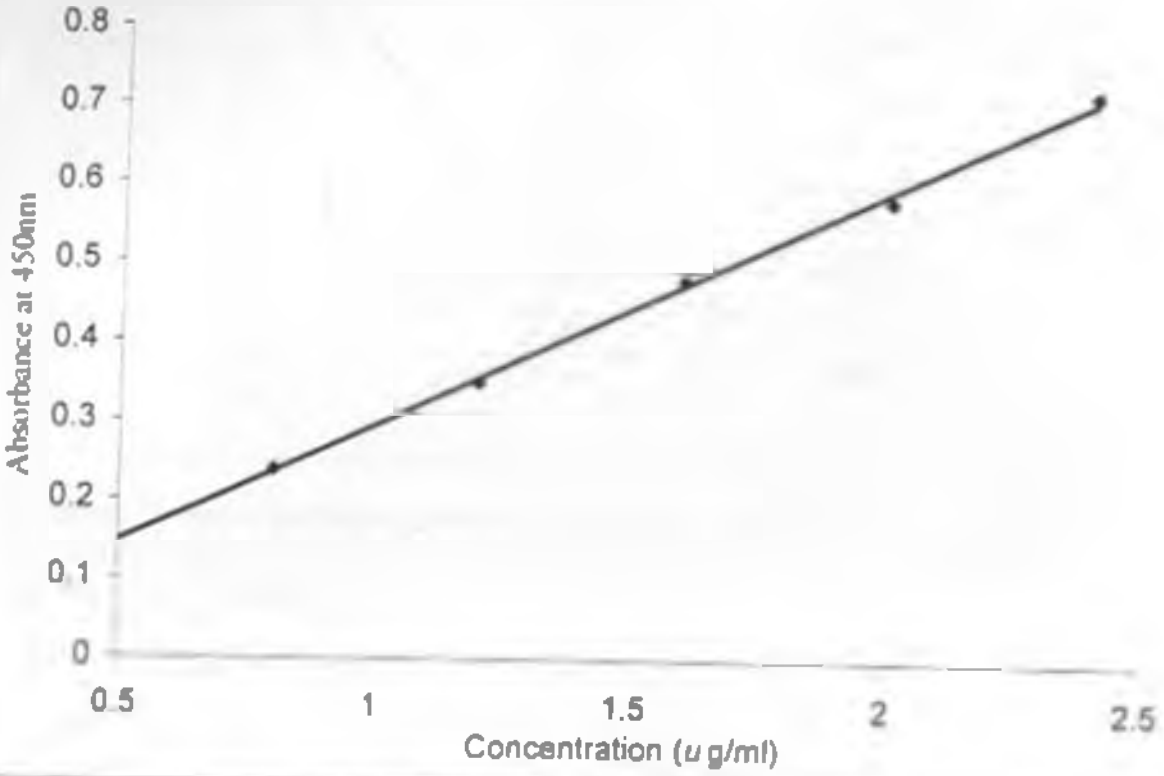
R- replication, T- type of packaging material, V- genotype, D- days, X- interaction ,* significance at P ≤ 0.05, DF- degrees of freedom and M-square- Mean square

Appendix 7. Analysis of variance table for beta-carotene contents (mg/100g) of sweet potato genotypes as affected by packaging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	1.42	1.36
T	3	46.853	21.735*
V	1	1649.439	120.656*
D	3	120.417	51.147*
T X V	3	27.731	0.818
T X D	9	8.92	5.566*
V X D	3	58.656	2.213
T X V X D	9	12.284	0.518
Experimental Error	93	0.672	0.934
Sampling Error	221	0.298	0.543

R- replication, T- type of packaging material, V- genotype, D- days, X- interaction ,*- significance at P ≤ 0.05, DF- degrees of freedom and M-square- Mean square.

Appendix 8. Beta-carotene standard curve

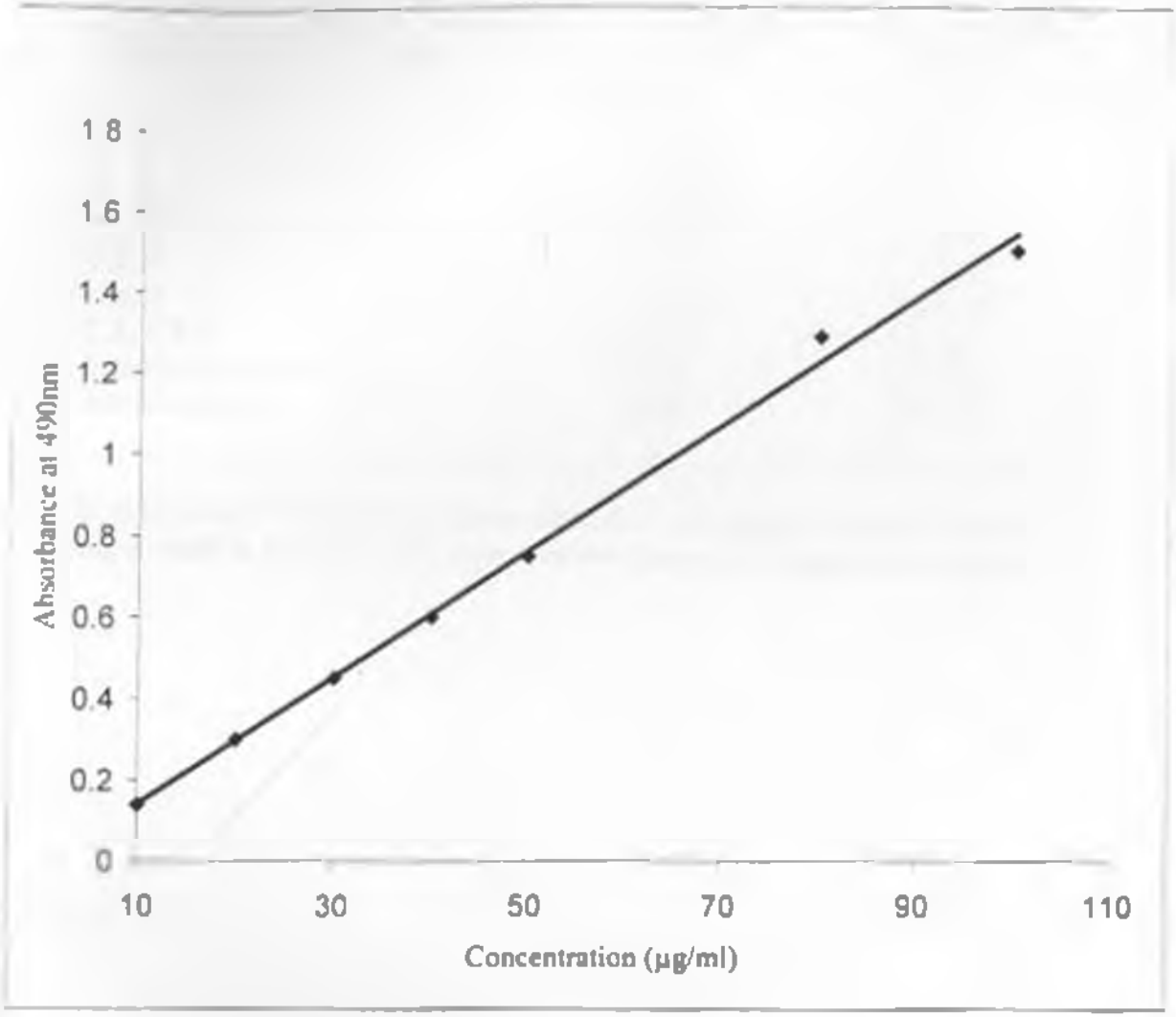


Appendix 9. Analysis of variance table for percent total sugars as affected by packaging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	0.059	3.973
T	3	5.035*	11.046*
V	1	23.403*	4.795
D	3	77.400*	70.941*
T X V	3	0.247	0.254
T X D	9	0.701*	1.484
V X D	3	1.424*	1.434
T X V X D	9	0.066	0.451
Ex. Error	93	0.123	1.408
Sp. Error	221		

R- replication, T- type of packaging material, V- genotype, X- interaction ,*- significance at $P \leq 0.05$, DF- degrees of freedom, M-square- Mean square. Ex. Error- Experimental error and Sp. Error- Sampling error.

Appendix 10. Glucose standard curve



Appendix 11 Analysis of variance table for total soluble solids as affected by packaging treatments.

		Experiment I	Experiment II
SOURCE	DF	M-square	M-square
R	3	0.307	0.156
T	3	0.213	0.602*
V	1	2.402*	0.170
D	3	13.394*	2.485*
T X V	3	0.305	0.856
T X D	9	0.121	1.226*
V X D	3	4.565*	2.105*
T X V X D	9	0.144	0.183
Experimental Error	93	0.22	0.274
Sampling Error	221	0.08	0.184

R- replication, T- type of packaging material, V- genotype, D- days, X- interaction ,*- significance at P ≤ 0.05, DF- degrees of freedom and M-square- Mean square.